GASOLINE FUEL

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        The present invention relates to fuels, particu-
larly gasoline fuels, and combustion methods therefor, and
5   methods for preparing gasoline fuels which, upon combus-
tion, minimize the release of CO, NOx, and/or hydrocarbon
emissions to the atmosphere.

        One of the major environmental problems con-
10 fronting the United States and other countries is atmo-
spheric pollution (i.e., "smog") caused by the emission of
gaseous pollutants in the exhaust gases from automobiles.
This problem is especially acute in major metropolitan
areas, such as Los Angeles, California, where the atmo-
15 spheric conditions and the great number of automobiles
account for aggravated air pollution.

        It is well known that the three primary gaseous
constituents, or pollutants, which contribute to air
20 pollution due to auto exhaust are nitrogen oxides (NOx),
carbon monoxide (CO), and unburned or incompletely burned
hydrocarbons (i.e., hydrocarbon components originally
present in the gasoline fuel which are not fully converted
to carbon monoxide or dioxide and water during combustion
25 in the automobile engine).

SUMMARY OF THE INVENTION

        The present invention provides gasoline fuels
30 from which a relatively low amount of gaseous pollutants,
and in particular one or more of NOx, CO, and hydrocarbons,
is produced during combustion in an automotive engine.
The invention provides methods for producing gasoline
fuels having such desirable properties. The invention
35 also provides methods of combusting such fuels in

automotive engines while minimizing emission of pollutants
released to the atmosphere, which in turn provides a
method for reducing air pollution, particularly in con-
gested cities and the like, when large volumes of auto-
5   motive fuel of the invention are combusted in a great
number of automobiles in a relatively small geographical
area.

        The present invention also provides a petroleum
10   refiner with knowledge of which properties of a gasoline
fuel to alter, and in which direction (i.e., increased or
decreased), so as to produce a gasoline fuel which will
reduce or minimize NOx, CO, and hydrocarbon emissions upon
combustion in an automotive engine.
15

        The present invention, in its broadest aspect,
is founded on the discovery that, when gasoline fuels are
produced, for example, by blending a plurality of hydro-
carbon-containing streams together so as to produce a
20   gasoline product suitable for combustion in an automotive
spark-induced internal combustion engine, improvements in
emissions of one or more pollutants selected from the
group consisting of CO, NOx, and hydrocarbons upon combus-
tion of the gasoline product in such an engine system can
25   be attained by controlling certain chemical and/or physical
properties of said gasoline product. For example, a first
hydrocarbon-containing stream boiling in the gasoline
range can be blended with a different hydrocarbon stream
at rates adjusted so as to effect at least one of the
30   properties of the first gasoline stream as follows:
         (1) decrease the 50% D-86 Distillation Point;
         (2) decrease the olefin content;
         (3) increase the paraffin content;
         (4) decrease the Reid Vapor pressure;
35   (5) increase the Research Octane Number;

(6) decrease the 10% D-86 Distillation Point;

(7) decrease the 90% D-86 Distillation Point; and

(8) increase the aromatic content

5 The greater the increase or decrease of the eight proper-
ties as set forth above, the greater the resulting benefit
in reducing emissions of one or more of CO, NOx, and
hydrocarbons.

10 For gasoline fuels in which one desires that
hydrocarbon emissions and/or CO emissions be minimized or
reduced, the principal factor influencing such emissions
is the 50% D-86 distillation point, with decreases therein
causing decreases in the hydrocarbon emissions. Fuels
15 generally prepared in accordance with this embodiment of
the invention have a 50% D-86 distillation point no
greater than 215° F. (101.6° C.), with the hydrocarbon and
CO emissions progressively decreasing as the 50% D-86
distillation point is reduced below 215° F. (101.6° C.).
20 Preferred fuels have a 50% D-86 Distillation Point of
205° F. (96.1° C.) or less. Best results are attained
with fuels having a 50% D-86 distillation point below
195° F. (90.6° C.).

25 For gasoline fuels in which one desires that
emissions of NOx be minimized or reduced, the principal
factor influencing such emissions is Reid Vapor pressure.
NOx emissions decrease as the Reid Vapor Pressure is
decreased (e.g., to 8.0 psi (0.54 atm) or less, preferably
30 to 7.5 psi (0.51 atm) or less, and even more preferably
below 7.0 psi (0.48 atm)). Of secondary importance with
respect to NOx emissions are the 10% D-86 Distillation
Point and the olefin content. In general, decreasing
olefin content (e.g., below 15 volume percent, preferably
35 to essentially zero volume percent) and/or decreasing the

10% D-86 Distillation Point (e.g., to values below 140° F. (60° C.)) will provide some reduction in NOx emissions. However, because it is contemplated that decreases in olefin content will be more acceptable to an oil refiner than decreasing the 10% D-86 Distillation Point suffi-ciently to significantly affect the NOx emissions, it is believed that, as a practical matter, it will be olefin content which will be the secondary variable providing the most flexibility to an oil refiner in altering the gasoline properties to reduce NOx emissions. (This is all the more the case inasmuch as, in general, if one wishes to decrease the Reid Vapor Pressure, it is usually necessary to increase the 10% Distillation Point.) Accordingly, best results are attained when both the olefin content is below 15 volume percent (preferably to zero) and the Reid vapor pressure is no greater than 7.5 psi--with it being highly desirable, if possible, to also maintain the 10% D-86 Distillation Point below 140° F. (60° C.).

In view of the foregoing, it can be seen that many modifications of the invention are possible, depend-ing upon which of the three pollutants one desires to reduce and the degree of reduction desired. For example, one can attain significant reductions in all three pollu-tants--hydrocarbons, CO, and NOx--by maintaining the 50% D-86 distillation point at or below about 215° F. (101.6° C.) and maintaining the Reid Vapor Pressure no greater than 8.0 psi (0.54 atm). Still better reductions can be obtained by maintaining the olefin content below 10 volume percent, or maintaining the 10% D-86 distillation point below 140° F. (60° C.), with still further reduc-tions being possible when both the olefin content and 10% D-86 Distillation Point are so maintained. Yet further reductions are possible by maintaining the 50% D-86 distillation point below 195° F. (90.6° C.), by reducing

the olefin content to below 5.0 vol.% (preferably to essentially zero), by decreasing the 10% D-86 Distillation Point to below 120° F. (49° C.), and/or by maintaining the Reid Vapor pressure below 7.0 psi (0.48 atm).

The presently preferred specifications proposed for commercial use for a gasoline produced in accordance with the invention are: (1) Olefin Content of 0%; (2) Reid Vapor Pressure of 7.5 psi (0.51 atm) maximum; and (3) 50% D-86 distillation point greater than 180° F. (82° C.) but no greater than 205° F. (96° C.). However, other fuels falling within the scope of the invention are also possible, for example, fuels meeting the following criteria:

(1) a 50% D-86 distillation point no greater than 215° F. (101.7° C.) and a Reid Vapor Pressure no greater than 8.0 psi (0.54 atm).

(2) a 50% D-86 distillation point no greater than 205° F. (96° C.) and an olefin content less than 3 percent by volume;

(3) a Reid Vapor Pressure no greater than 8.0 psi (0.54 atm) and containing at least 40 volume percent paraffins;

(4) a Reid Vapor Pressure no greater than 7.5 psi (0.51 atm) and containing essentially no methyl tertiary butyl ether but less than 15 volume percent olefins.

One of the main advantages of the invention is that a less polluting gasoline fuel is provided that can be easily prepared in a petroleum refinery or the like. That is, in a typical refinery in which gasoline is produced, it is necessary or at least desirable in most instances to blend the hydrocarbon stocks so as to produce gasolines of specified Reid Vapor Pressure, olefins content, etc. Thus, the only difference is that now the

refinery will blend the stocks in light of the information provided herein such that the NOx, CO, and hydrocarbon emissions are reduced as much as possible or practicable, given the individual situation (the blend stocks available,

5   refining capacity, etc.) facing the particular refinery.

It will be understood in this disclosure and the claims to follow that the words "reduce" and "reducing" in the context of lowering NOx, CO, or hydrocarbon emissions

10   are relative terms. Obviously, the simplest way to produce no emissions is to combust no fuel; and equally obviously, almost any combustion of a gasoline fuel will produce some emissions and thus produce greater emissions than if no fuel were combusted. However, on the assumption that the

15   motoring public would find the consequences of combusting no fuel rather unattractive, logic dictates in the context of this invention that "reducing" is in comparison to the results achievable with other fuels. For example, for those embodiments of the invention in which the 50% D-86

20   Distillation Point is controlled to no more than 200° F. (93° C.), the emissions will be reduced in comparison to the otherwise identical fuel but having a higher 50% D-86 Distillation Point when combusted in the same automotive engine (or in an equivalent number of automotive engines)

25   operating for the same time period in the same way.

BRIEF DESCRIPTION OF THE DRAWING

The invention can be best understood with

30   reference to the drawing, the figures of which provide graphical or tabular data derived from the experiments described hereinafter with respect to Examples 2 and 3.

More particularly, Figure 1 is a graph of CO

35   emission values for 22 different fuels tested in six

different automobiles. Each data point on the graph is an
average of a plurality of runs for each fuel-automobile
combination.

5   Figure 2 is a graph of NOx emission values for
22 different fuels tested in six different automobiles.
Each data point on the graph is an average of a plurality
of runs for each fuel-automobile combination.

10   Figure 3 is a graph of hydrocarbon emission
values for 22 different fuels tested in six different
automobiles. Each data point on the graph is an average
of a plurality of runs for each fuel-automobile combination.

15   Figure 4 is a graph of CO emission values for 22
different fuels tested in four different automobiles.
Each data point on the graph is an average of a plurality
of runs for each fuel-automobile combination.

20   Figure 5 is a graph of NOx emission values for
22 different fuels tested in four different automobiles.
Each data point on the graph is an average of a plurality
of runs for each fuel-automobile combination.

25   Figure 6 is a graph of hydrocarbon emission
values for 22 different fuels tested in four different
automobiles. Each data point on the graph is an average
of a plurality of runs for each fuel-automobile combination.

30   Figure 7 is a table, based on data derived from
the experiments in Examples 2 and 3, which identifies the
most significant variables which increase emissions of CO
when the variable is increased (as identified by one or
more + signs) or which decrease emissions of CO when the
35   variable is decreased (as identified by one or more - signs).

Figure 8 is a table, based on data derived from the experiments in Examples 2 and 3, which identifies the most significant variables which increase emissions of NOx when the variable is increased (as identified by one or more + signs) or which decrease emissions of NOx when the variable is decreased (as identified by one or more - signs).

Figure 9 is a table, based on data derived from the experiments in Examples 2 and 3, which identifies the most significant variables which increase emissions of hydrocarbons when the variable is increased (as identified by one or more + signs) or which decrease emissions of hydrocarbons when the variable is decreased (as identified by one or more - signs).

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to gasoline compositions having chemical and physical properties which reduce and/or minimize the amount of gaseous pollutants emitted during combustion. In particular, the invention aims to reduce and/or minimize the emissions of hydrocarbons, NOx and/or CO during combustion in an automotive engine.

Gasolines are well known fuels, generally composed of a mixture of hydrocarbons boiling at atmospheric pressure in a very narrow temperature range, e.g., 77° F. (25° C.) to 437° F. (225° C.). Gasolines are typically composed of mixtures of aromatics, olefins, and paraffins, although some gasolines may also contain such added non-hydrocarbons as alcohol (e.g., ethanol) or oxygenates (e.g., methyl tertiary butyl ether). Gasolines may also contain various additives, such as detergents, anti-icing agents, demulsifiers, corrosion inhibitors, dyes, deposit

modifiers, as well as octane enhancers such as tetraethyl
lead. However, the preferred fuels contemplated in the
invention are unleaded gasolines (herein defined as contain-
ing a concentration of lead no greater than 0.05 gram of
5   lead per gallon (0.013 gram of lead per liter)). The pre-
ferred fuels will also have a Research Octane Number (RON)
of at least 90. Octane value (R/2+M/2) for regular gaso-
line is generally at least 87 and for premium at least 92.

10   At present, most gasolines suitable for combus-
tion in automotive spark-ignition engines conform to the
requirements of ASTM D4814-89 specifications, which
specifications are herein incorporated by reference in
their entirety. Such gasolines fall into five different
15   volatility classes, with some of the specifications
therefor set forth in the following Table 1:

TABLE 1

Properties	Class A	Class B	Class C	Class D	Class E
RVP (psi) max	9.0	10.0	11.5	13.5	15.0
(atm) max	0.6	0.7	0.8	0.9	1.0
Dist. 10% (°F) max	158	149	140	131	122
(°C) max	70	65	60	55	50
Dist. 50% (°F) min-max	170-250	170-245	170-240	170-235	170-230
(°C) min-max	77-121	77-118	77-116	77-113	77-110
Dist. 90% (°F) max	374	374	365	365	365
(°C) max	190	190	185	185	185
End Point (°F) max	437	437	437	437	437
(°C) max	225	225	225	225	225

The most preferred gasolines produced in accordance with the invention are those which meet the requirements of one or more of the five classes specified in Table 1.

5   In the present invention, the gasoline is formulated, usually by appropriately blending various hydrocarbon streams in a refinery, to reduce or minimize emissions of CO, NOx, and/or hydrocarbons upon combustion in a spark-induced automotive internal combustion engine.
10   It has been discovered in the present invention, for many automotive engines, that the amount of pollutants emitted upon combustion is closely in accord with the following equations:

15   Equation 1

CO (gm per mile) = K_1 x (D-86 Dist. 50% Point in ° F.)
                 + K_2 x (D-86 Dist. 90% Point in ° F.)
                 - K_3 x (Vol. % Paraffins)
20

Equation 2

NOx (gm per mile) = K_4 x (Vol. % Olefins)
                  - K_5 x (Vol. % Paraffins)
25   + K_6 x (D-86 Dist. 10% Point in ° F.)
                  + K_7 x (RVP in psi)

Equation 3

30   HC (gm per mile) = K_8 x (Vol. % Olefins)
                  - K_9 x (Research Octane Number)
                  + K_{10} x (D-86 Dist. 50% Point in ° F.)

where each K value in the foregoing equations is a positive
35   number. The K values will be fixed for a particular engine

in a particular car but can be readily determined. For example, for a 1988 Oldsmobile Regency 98 equipped with a 3.8 liter V-6 Engine, the K values are such that the equations are as follows:

5

Equation 4

CO (gm per mile) = 0.00937 x (D-86 Dist. 50% Point in ° F.)

            + 0.00133 x (D-86 Dist. 90% Point

                                in ° F.)

            - 0.00828 x (Vol. % Paraffins)

Equation 5

NOx (gm per mile) = 0.00503 x (Vol. % Olefins)

            - 0.00060 x (Vol. % Paraffins)

            + 0.00087 x (D-86 Dist. 10% Point

                                in ° F.)

            + 0.0159 x (RVP in psi)

20

Equation 6

HC (gm per mile) = 0.00245 x (Vol. % Olefins)

            - 0.00104 x (Research Octane Number)

            + 0.00109 x (D-86 Dist. 50% Point

                                in ° F.)

From the foregoing equations, and from the relative sizes of the various K values and the typical values which would pertain for the properties by which the K values are multiplied (e.g., Vol. % Olefins, Research Octane Number, etc.), the following conclusions are obtained for the 1988 Oldsmobile Regency 98 and similar automobiles: For CO emissions, although decreasing the 90% D-86 distillation point has some impact on lowering CO emissions, the

paraffin content and the 50% D-86 Distillation point
influence such emissions much more substantially. All
other things being equal, increasing the paraffin content
or reducing the 50% D-86 distillation point will provide
5   the most dramatic effects in reducing CO emissions, with
best results being attained when both the paraffin content
is substantially increased and the 50% D-86 distillation
point is substantially reduced. In like manner, it can be
seen that by decreasing the 10% D-86 Distillation Point
10   and/or by increasing the paraffin content, some decrease
in the NOx emissions will be produced. However, far more
influential on the NOx emissions are the olefin content
and the Reid Vapor Pressure, both of which cause substan-
tial reductions in NOx emissions as they are substantially
15   decreased. For hydrocarbon emissions, inspection of the
equations indicates, since one is usually constrained to
no more than a 5 unit change in Research Octane Number in
the range of about 90 to 95, that it will not normally be
practicable to alter the Research Octane Number suffi-
20   ciently to have a significant impact on the hydrocarbon
emissions. Accordingly, although some reduction in hydro-
carbon emissions can be attained by increasing the Research
Octane Number, the most practical way to significantly
lower the hydrocarbon emissions while retaining other bene-
25   ficial properties of the fuel is by lowering the olefin
content and/or by lowering the 50% D-86 Distillation Point.

The foregoing equations also provide those
skilled in the art, again as to a 1988 Oldsmobile Regency
30   98 and similar automobiles, with information as to how to
lower the reductions of not just CO, NOx, or hydrocarbons,
but also any combination thereof. For example, if one is
interested in reducing the emission levels of all three,
the equations show, if all other properties are held
35   essentially constant, that reducing the Reid Vapor Pressure

and the 50% D-86 distillation point will decrease the
emissions of CO, NOx, and hydrocarbons. Likewise,
decreases in these three pollutants can be attained by
decreasing the 50% D-86 Distillation Point and decreasing
5   the olefin content.

The above equations also lead to the following
conclusions (again as to the 1988 Oldsmobile Regency and
similar automobiles):
10

All other properties of a gasoline fuel being
substantially the same,

1. As the 50% D-86 Distillation Point is progres-
15   sively decreased, progressively greater reductions in CO
and hydrocarbons emissions will result;

2. As the olefin content is progressively
decreased, progressively greater reductions in NOx and
20   hydrocarbons emissions will result;

3. As the paraffin content is progressively
increased, progressively greater reductions in CO and NOx
emissions will result;
25

4. As the Reid Vapor pressure is progressively
decreased, progressively greater reductions in NOx emis-
sions will result;

30   5. As the Research Octane Number is progres-
sively increased, progressively greater reductions in
hydrocarbon emissions will result;

6. As the 10% D-86 Distillation Point is
35   progressively decreased, progressively greater reductions
in NOx emissions will result;

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7. As the 90% D-86 Distillation Point is progressively decreased, progressively greater reductions in CO emissions will result.

5   And, of course, combining any of the above seven factors will lead to yet progressively greater reductions. However, as will become evident in light of the data in the examples to follow, the most important of the foregoing factors are Reid Vapor Pressure (for reducing NOx) and the

10   50% D-86 Distillation Point (for reducing CO and hydrocarbon emissions). Of secondary importance in reducing NOx are the olefin content and the 10% D-86 Distillation Point, with the former being of greater influence than the latter. The following Examples serve to further illustrate

15   the inventive concept and are not intended to be construed as limitations on the invention, which is defined by the claims.

EXAMPLE 1

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       A total of 22 different unleaded gasoline fuels was tested in a 1988 Oldsmobile Regency 98 automobile equipped with a 3800 cc V-6 engine. This automobile was selected because it represented a high sales volume

25   product with close to the current state-of-the-art emission technology. The emission system was closed loop control on the air to fuel ratio with a three way catalyst system and adaptive learning capability. The automobile had been previously driven for 38,000 miles to stabilize the Octane

30   Requirement Increase.

       The properties of each of the 22 fuels are shown in the following Table 2.

35

TABLE 2

GASOLINE PROPERTIES

Blend Designation	Aromatics Vol.% by FIA	Olefins Vol.% by FIA	Paraffins Vol.% by FIA	MTBE Vol.% by IR	Research Octane Number	Motor Octane Number	D86 Dist. 10% point (°F)	D86 Dist. 50% point (°F)	D86 Dist. 90% point (°F)	Reid Vapor Pressure psi
AR3951-1	7.60	0.2	92.20	0.0	93.6	89.2	131	209	299	9.00
AR3951-2	6.60	0.0	93.40	0.0	90.3	86.8	111	203	383	10.10
AR3951-3	43.30	9.5	47.20	0.0	96.1	84.5	126	235	312	8.90
AR3951-4	47.50	8.3	44.20	0.0	95.8	84.4	150	251	355	5.60
AR3951-5	38.15	0.2	61.65	0.0	91.3	82.7	166	221	284	6.37
AR3951-6	11.90	15.9	55.00	17.2	91.5	82.2	128	174	368	8.50
AR3951-7	36.80	0.6	48.30	14.3	95.0	86.1	120	224	405	9.70
AR3951-8	12.30	12.7	60.40	14.6	94.4	85.1	120	185	341	9.20
AR3951-9	44.10	11.3	44.60	0.0	96.6	84.5	128	229	305	8.80
AR3951-10	4.50	19.6	75.90	0.0	94.4	84.8	127	195	310	9.70
AR3951-11	51.60	11.6	36.80	0.0	95.9	84.0	149	308	382	6.50
AR3951-12	28.80	0.6	55.70	14.9	92.9	85.7	128	210	271	9.55
AR3951-13	14.70	17.9	51.50	15.9	91.6	82.2	127	169	392	7.90
AR3951-14	11.60	12.9	75.50	0.0	90.7	82.8	107	193	416	9.20
AR3951-15	9.50	0.0	90.50	0.0	88.6	85.1	158	207	329	6.25
ULRG	58.30	0.4	30.40	10.9	107.0	95.7	160	218	229	5.35
G3297-PJ	40.90	11.1	48.00	0.0	96.4	85.2	120	214	339	8.20
A/O 1111	19.50	4.1	76.40	0.0	90.6	84.4	123	196	282	8.80
A/O 2222	48.30	21.0	15.40	15.3	99.0	86.1	125	221	356	8.80
A/O AVE	30.70	9.5	59.80	0.0	92.2	82.7	112	218	315	8.70
ARCO EC-1	20.70	10.8	61.40	7.1	92.8	84.0	125	198	348	8.20
SU2000E	40	9	45.3	5.7	97.9	86.7	139	224	321	8.0

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The fuels were tested in random order with no
back to back runs of the same fuel. At first, only the 15
test fuels (designated AR3951-1 through AR3951-15) were
run, in random order, and all more than once. However,

5   every fifth run was conducted with fuel G3297-PJ as a
control to evaluate systematic error. Each fuel was
tested in accordance with the Federal Test Procedure
except that (1) instead of allowing the engine between
tests to cool down in still air for 10 to 12 hours at 68°

10   to 86° F. (20.0 to 30.0° C.), the engine was subjected for
4.75 hours to a 70° F (21.1° C.) wind of 50 miles per hour
(80.5 km/hr) and (2) instead of a Clayton dynamometer, a
General Electric dynamometer was used. It will be noted
that the 15 test fuels were purposely blended to provide

15   widely different values for the ten properties shown in
Table 2. The emissions data derived from combusting the
15 different test fuels were then analyzed by computer
program using the SAS system commercially available from
SAS Institute Inc. In this program, the results of the

20   runs with the 15 different fuels were regressed against
each of the 10 variables shown in Table 2, as well as
against all possible combinations thereof, searching for
an equation for each of the three pollutants of interest
(NOx, CO, and hydrocarbons) defined by the minimum number

25   of variables that gives the best surface fit based on the
R squared value. As a result, the Equations 4, 5, and 6
hereinbefore presented were derived as the equations which
best define the amount of pollutants (in grams per
mile) emitted as a function of the properties of the fuel

30   combusted in the 1988 Regency vehicle.

After developing the foregoing equation, the
other fuels shown in Table 2 were tested, most in multiple
runs, and again with the G3297-PJ fuel being used in every

35   fifth run. These fuels were tested for the purpose of

checking the accuracy of the foregoing equations in
forecasting emissions for new fuel, i.e., they were used
as "check fuels."

5   The emissions data for all runs--the test,
control, and check fuels--as well as the calculated
emissions according to the foregoing developed equations,
are tabulated in Table 3, with it being specifically noted
that the order shown in Table 3 is not the exact order in
10   which the fuels were tested.

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TABLE 3

Exp.	Fuel Designation	CO g/mile	NOx g/mile	HC g/mile	Calculated CO g/mile	Calculated NOx g/mile	Calculated HC g/mile
1	AR3951-1	1.106	0.196	0.100	1.593	0.203	0.131
2	AR3951-2	0.948	0.186	0.094	1.638	0.201	0.127
3	AR3951-3	1.590	0.264	0.145	2.226	0.271	0.179
4	AR3951-4	2.228	0.252	0.193	2.458	0.235	0.194
5	AR3951-5	2.034	N.D.	0.157	1.938	0.218	0.146
6	AR3951-6	1.637	0.280	0.143	1.664	0.293	0.133
7	AR3951-7	2.335	0.232	0.166	2.238	0.233	0.147
8	AR3951-8	1.374	0.257	0.118	1.687	0.278	0.135
9	AR3951-9	2.068	0.286	0.165	2.182	0.281	0.177
10	AR3951-10	1.357	0.307	0.134	1.611	0.318	0.162
11	AR3951-11	3.752	0.273	0.268	3.089	0.269	0.264
12	AR3951-12	1.738	0.278	0.154	1.867	0.233	0.134
13	AR3951-13	2.275	0.311	0.159	1.678	0.295	0.133
14	AR3951-14	1.959	0.271	0.147	1.737	0.259	0.148
15	AR3951-15	1.654	0.190	0.114	1.628	0.183	0.133
16	ULRG	1.901	0.200	0.142	2.096	0.208	0.127
17	AR3951-14	1.708	0.255	0.156	1.737	0.259	0.148
18	G3297-PJ	2.267	0.273	0.187	2.059	0.262	0.160
19	G3297-PJ	1.784	0.254	0.167	2.059	0.262	0.160
20	G3297-PJ	1.975	0.288	0.160	2.059	0.262	0.160
21	G3297-PJ	2.265	0.263	0.180	2.059	0.262	0.160
22	AR3951-1	1.269	0.200	0.137	1.593	0.203	0.131
23	AR3951-1	1.535	0.200	0.135	1.593	0.203	0.131

TABLE 3 (Continued)

Exp.	Fuel Designation	FTP CO Emissions	FTP NOx Emissions	FTP HC Emissions	Calculated CO Emissions	Calculated NOx Emissions	Calculated HC Emissions
24	AR3951-2	1.253	0.163	0.133	1.638	0.201	0.127
25	AR3951-3	1.692	0.244	0.148	2.226	0.271	0.179
26	AR3951-4	2.835	0.274	0.235	2.458	0.235	0.194
27	AR3951-5	1.764	0.250	0.159	1.938	0.218	0.146
28	AR3951-6	1.338	0.268	0.115	1.664	0.293	0.133
29	AR3951-7	2.059	0.223	0.146	2.238	0.233	0.147
30	AR3951-8	1.633	0.271	0.140	1.687	0.278	0.135
31	AR3951-9	1.952	0.281	0.157	2.182	0.281	0.177
32	AR3951-11	3.443	0.237	0.272	3.089	0.269	0.264
33	AR3951-12	1.959	0.266	0.146	1.867	0.233	0.134
34	AR3951-13	2.127	0.320	0.156	1.678	0.295	0.133
35	AR3951-14	2.552	0.284	0.182	1.737	0.259	0.148
36	G3297-PJ	2.240	0.263	0.204	2.059	0.262	0.160
37	G3297-PJ	2.059	0.240	0.168	2.059	0.262	0.160
38	G3297-PJ	2.322	0.278	0.172	2.059	0.262	0.160
39	G3297-PJ	1.890	0.286	0.169	2.059	0.262	0.160
40	G3297-PJ	2.339	0.252	0.192	2.059	0.262	0.160
41	A/O 1111	1.641	0.296	0.173	1.579	0.222	0.129
42	A/O 2222	1.999	0.251	0.172	2.417	0.345	0.189
43	A/O AVE	2.162	0.298	0.210	1.798	0.248	0.145
44	A/O AVE	2.476	0.274	0.167	1.798	0.248	0.145
45	ARCO EC-1	1.651	0.271	0.139	1.810	0.257	0.146

TABLE 3 (Continued)

Exp.	Fuel Designation	FTP CO Emissions	FTP NOx Emissions	FTP HC Emissions	Calculated CO Emissions	Calculated NOx Emissions	Calculated HC Emissions
46	ARCO EC-1	1.517	0.255	0.139	1.810	0.257	0.146
47	SU2000E	1.738	0.203	0.166	2.104	0.256	0.164
48	AR3951-15	1.511	0.244	0.152	1.553	0.172	0.125
49	G3297-PJ	1.862	0.284	0.161	2.059	0.262	0.160
50	AR3951-5	2.012	0.261	0.201	1.938	0.218	0.146
51	A/O 1111	1.545	0.293	0.224	1.579	0.222	0.129
52	A/O 2222	1.963	0.246	0.157	2.417	0.345	0.189
53	ULRG	1.769	0.217	0.139	2.096	0.208	0.127

The multiple test emissions data for each of the check fuels and the control fuel were then averaged, set against the calculated values, the deviation from the calculated value then determined, and compared against the standard deviation, which in turn was calculated from only the data pertaining to the control fuel G3297-PJ. These data are set forth in the following Table 4:

TABLE 4

Emis.	Fuel	Actual g/mi	Calculated g/mi	Deviation	Standard Deviation
CO	ULRG	1.835	2.096	0.261	0.205
CO	G3297-PJ	2.127	2.059	0.067	0.205
CO	Arco EC1	1.584	1.810	0.226	0.205
CO	A/O 1111	1.593	1.579	0.014	0.205
CO	A/O 2222	1.981	2.417	0.436	0.205
CO	SU2000E	1.738	2.104	0.366	0.205
CO	A/O AVE	2.319	1.798	0.521	0.205
NOx	ULRG	0.209	0.207	0.002	0.0162
NOx	G3297-PJ	0.266	0.261	0.005	0.0162
NOx	Arco EC1	0.263	0.256	0.007	0.0162
NOx	A/O 1111	0.295	0.222	0.073	0.0162
NOx	A/O 2222	0.249	0.345	0.096	0.0162
NOx	SU2000E	0.203	0.256	0.053	0.0162
NOx	A/O AVE	0.286	0.248	0.038	0.0162
HC	ULRG	0.141	0.127	0.014	0.0142
HC	G3297-PJ	0.178	0.160	0.017	0.0142
HC	Arco EC1	0.139	0.146	0.007	0.0142
HC	A/O 1111	0.198	0.129	0.069	0.0142
HC	A/O 2222	0.165	0.189	0.024	0.0142
HC	SU2000E	0.166	0.164	0.002	0.0142
HC	A/O AVE	0.189	0.145	0.044	0.0142

It will be seen that, in most cases, the deviations shown
in Table 4 are well within three times the standard
deviation. In turn, this means that the equations accur-
ately define the scientific phenomena at work within
5   normal realms of variabilities.

<div align="center">EXAMPLE 2</div>

     In this example, 22 gasoline fuels, including 15
10   test fuels A through N and P, one control fuel, Q, and six
check fuels, R, S, T, V, W and X were run in six different
automobiles. The properties of the 22 gasolines used are
shown in the following Table 5.

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TABLE 5

GASOLINE PROPERTIES

Blend Desig- nation	Aromatics Vol.% by FIA	Olefins Vol.% by FIA	Paraffins Vol.% by FIA	MTBE Vol.% by IR	Research Octane Number	Motor Octane Number	D86 Dist. 10% point (°F)	D86 Dist. 50% point (°F)	D86 Dist. 90% point (°F)	Reid Vapor Pressure psi
A	9.6	0.0	90.4	0.0	94.0	89.5	128	206	291	9.23
B	5.3	0.0	94.7	0.0	91.1	87.4	106	178	290	11.45
C	48.8	10.3	41.0	0.0	97.0	84.7	122	225	300	9.14
D	46.6	11.4	42.1	0.0	96.2	84.0	147	236	334	6.63
E	39.4	0.4	60.1	0.0	97.3	83.2	164	219	271	6.46
F	9.8	16.8	73.3	15.9	92.0	83.0	121	161	231	9.35
G	32.8	0.6	66.6	13.7	96.6	87.5	107	194	296	11.54
H	12.7	15.0	72.3	14.0	94.3	84.8	119	180	302	9.88
I	46.4	12.6	41.0	0.0	97.3	84.9	126	220	294	8.73
J	4.8	6.2	89.1	0.0	93.9	84.9	119	188	290	9.65
K	45.6	13.6	40.8	0.0	95.9	83.9	135	274	370	7.60
L	31.0	0.2	68.8	14.4	93.3	85.6	125	206	262	9.43
M	15.9	15.3	68.8	15.8	92.1	82.9	114	157	368	9.77
N	12.8	11.6	75.6	0.0	90.7	83.2	107	185	403	10.51
P	10.6	0.0	89.4	0.0	89.7	85.8	144	204	318	7.07
Q	31.8	9.9	58.3	0.0	92.1	82.7	129	220	331	8.31
R	52.0	21.9	26.1	14.6	98.8	85.5	130	224	358	8.37
S	21.1	3.9	75.0	0.0	91.0	84.3	129	199	284	8.44
T	30.2	0.0	69.8	0.0	88.5	81.2	127	182	293	8.00
V	23.3	6.0	70.7	0.0	92.0	83.5	132	196	319	7.96
W	25.6	11.8	62.5	10.1	97.7	86.7	134	215	335	8.12
X	38.5	0.0	61.5	0.0	94.8	85.0	123	211	326	7.63

The automobiles (and accompanying engines) utilized were:
1. 1988 Oldsmobile 98 Regency--3.8 liter V-6
2. 1989 Ford Taurus--3.0 liter V-6
3. 1990 Toyota Camry--2.0 liter 4 cylinders
5   4. 1989 GM Cutlass Calais--3.8 liter V-6
5. 1990 Ford Lincoln--5.0 liter V-8
6. 1990 Dodge Shadow--2.5 liter 4 cylinders

10   The fuels were tested in the foregoing automobiles in the same manner as described in Example 1 except that the control fuel was used in every sixth run and the Federal Test Procedure (FTP) was followed exactly. Each fuel was tested at least twice, many three times, and some four times, in each of the vehicles.

15

The CO, NOx, and hydrocarbon emission data obtained by the Federal Test Procedure for each fuel in a given automobile were averaged, and then plotted respectively in the graphs in Figures 1, 2, and 3. (Thus, each
20   data point in Figures 1 through 3 is an average of the values obtained for each automobile with the specified fuel.) Given the great number of fuels and automobiles tested, each of the three graphs shows a remarkable similarity in the overall shape of the curves in the
25   graphs. It is clearly evident from these figures that the general effect of a given fuel is the same for different vehicles, with only the magnitude of the effect varying.

EXAMPLE 3

30

In this example, Example 2 was repeated except on the following automobiles (and accompanying engines):
1. 1985 Ford Tempo--2.3 liter 4 cylinders
2. 1984 GM Caprice--5.0 liter V-8
35   3. 1988 Honda Accord--2.0 liter 4 cylinders
4. 1985 GM Suburban--5.7 liter V-8

The fuels were tested in the foregoing automobiles in the same manner as described in Example 2. The emission data obtained were averaged and plotted on Figures 4 through 6, and once again, the results show a
5 remarkable consistency in the effects of a given fuel.

In all, for Examples 2 and 3, a total of over 500 FTP runs was made so as to provide a large enough data base to ensure the validity of the results. It should be
10 noted that Examples 2 and 3, and the figures of the drawing pertaining to each, focused on automobiles and engines which were dissimilar in many respects. However, the automobiles in Example 2 all had adaptive learning computers with fuel-to-air feedback control loops whereas
15 those in Example 3 did not. The figures thus show that groups of cars with these similar engineering features behave similarly to changes in the fuel, which in turn shows the universality of one of the inventive concepts. The automobiles of Examples 2 and 3 were chosen because of
20 their high commercial sales. The automobiles of Example 2 were all relatively recent models while those of Example 3 were generally older. All but one of the Example 3 automobiles had carburetor systems whereas all of those in Example 2 had fuel injection systems.
25

The data derived in Examples 2 and 3 were analyzed by the same computer program as described for Example 1, searching, as in Example 1, for an equation for each automobile which would provide a value for NOx, CO,
30 and hydrocarbon emissions as a function of the minimum number of fuel properties. Not every equation so derived conformed to the generalized equation set forth hereinbefore; some, for example, showed a minor increase in hydrocarbon emissions with increases in aromatics content.
35 Nevertheless, many of the equations did fit the generalized

equation set forth hereinbefore, and more importantly, the
data overall validated the fact that the most important
factors as shown in the generalized Equations 1 to 3
proved almost universally most significant for each

5   automobile.

More specifically, where much of the previous
discussion was limited to 1988 Oldsmobile Regency 98 and
similar automobiles, the data in tables 7 to 9--which were

10   obtained from the data from which Figures 1 to 6 were
derived--indicate that some variables universally or
essentially universally affect emissions from automobile
engines, others are limited to one or only a few vehicles,
and yet others affect a particular pollutant in about 50%

15   of the vehicles.

More specifically still, in the tables of
Figures 7 to 9 there are indicated for each automobile
tested in Examples 2 and 3 those factors which proved to

20   be significant in increasing the specified emission when
the variable is increased (as indicated by one or more +
signs) and significant in decreasing the specified emission
when the variable is increased (as indicated by one or
more - signs). Those variables which dramatically affect

25   emissions (i.e., principal factors) are indicated by more
than one + or - signs, with increasing numbers of + or -
signs indicating increased significance for that variable.
Those variables which are of least importance among the
significant variables are indicated by a (+) or (-) sign.

30   (Also shown in Figures 7 to 9 are the values obtained by
summing the square of all the data predicted by the
particular equation for each automobile for a particular
pollutant and dividing by the sum of the square of all the
data actually obtained for the automobile. It will be

35   recognized that, the closer such value is to 1.0, the

better the equation defines the effect under consideration. In the case of Figures 7 to 9, 29 of the 30 values are above 0.9 and only one is below--and that scarcely below at 0.894. Accordingly, it was determined that the equations for each of the automobiles was statistically accurate, and that therefore the data derived therefrom--as shown in Figures 7 to 9--would meaningfully point to those variables which would have a statistically significant effect upon the emission characteristics from a given automobile in Figures 7 to 9.)

When the data of Examples 2 and 3 are analyzed as shown in Figures 7 to 9, the following facts stand out as most significant:

1. Decreases in the 50% D-86 Distillation Point caused decreases in CO and hydrocarbon emissions for all of the automobiles.

2. Decreases in the Olefin Content caused reductions in NOx emissions from all the vehicles.

3. Decreases in the 10% D-86 Distillation Point caused reductions in NOx emissions from all the vehicles.

4. Decreases in Reid Vapor Pressure caused reductions in NOx emissions from all the vehicles but one.

Accordingly, from the data in Figures 7 to 9, it can be seen that for automobiles in general that decreasing any of the variables 1 to 4 above will have a positive effect, especially for any large population of automobiles. In turn, it can be appreciated that the preferred fuels of the invention will be prepared (e.g., by appropriate blending in a refinery) so as to decrease each of the

foregoing variables, and in particular, the 50% D-86
Distillation Point, the Reid Vapor Pressure, and the
Olefin content, all three of which are more significantly
(and easily) decreasable in refinery practice than the 10%
5   D-86 distillation Point.

     Presently, the most commercially attractive fuel
producible in accordance with the invention has the
following properties: (1) Olefin Content of 0%; (2) Reid
10   Vapor Pressure of 7.5 psi (0.51 atm) maximum; and (3) 50%
D-86 distillation point greater than 180° F. (82° C.) but
no greater than 205° F. (96° C.).

     Where it is desired to take advantage of the
15   emission reductions attainable by varying the 50% D-86
distillation point, this value usually is no greater than
215° F. (101.6° C.), e.g., no greater than 210° F.
(98.9° C.) but preferably is no greater than 205° F.
(96.1° C.), e.g., less than 203° F. (95° C.), or less than
20   200° F. (93.3° C.), or less than 198° F. (92.2° C.), more
preferably less than 195° F. (90.6° C.), e.g., less than
193° F. (89.4° C), or less than 190° F. (87.8° C.), or
less than 187° F. (86.1° C.), and most preferably less
than 185° F. (85.0° C.), e.g., less than 183° F. (83.9° C.).
25   In general, the 50% D-86 Distillation Point is above
170° F. (77° C.) and most often above 180° F. (82.2° C.).

     Where it is desired to take advantage of the
emission reductions attainable by varying the olefin
30   content, this value is generally maintained less than 15
volume percent, with decreasing values providing progres-
sively improved results. Thus, it is contemplated that
each unit reduction, e.g., to values below 14, below 13,
below 12, below 11, below 10, below 9, below 8, below 7,
35   below 6, below 5, below 4, below 3, below 2, below 1

providing progressively better results, with values of 0.5 or less and essentially zero providing the best results possible.

5   Where it is desired to take advantage of reductions attainable by reducing the Reid Vapor Pressure, the gasoline will generally have a Reid Vapor Pressure specification of 8.0 psi (0.54 atm) max., most often less than 8.0 psi (0.54 atm), preferably no greater than 7.5
10   psi (0.51 atm), even more preferably no greater than 7.0 psi (0.48 atm), and most preferably of all, no greater than 6.5 psi (0.44 atm).

      Where the emissions reductions attainable by
15   reducing the 10% D-86 Distillation Point is desired, this value is most often maintained no greater than 140° F. (71° C.), preferably no more than 135° F. (57.2° C.), even more preferably no more than 130° F. (54° C), and most preferably of all, no more than 122° F. (48.9° C.).
20

      It can also be seen from the data in Figure 7 that the paraffin content has an effect on 50% of the automobiles with respect to reducing CO, i.e., progressively increasing the paraffin content progressively
25   decreases the CO emitted. Accordingly, where it is desired to take advantage of these facts, the paraffin content would be increased to above 40 volume percent, usually above 50 volume percent, most often to above 65 volume percent, preferably above 68 volume percent, more
30   preferably above 70 volume percent, e.g., above 72 volume percent, even more preferably above 75 volume percent, e.g., above 77 volume percent, and most preferably, above 80 volume percent, e.g., above 82 volume percent, and most preferably of all, above 85 volume percent, e.g., above 87
35   or 90 volume percent.

Likewise, 60% of the automobiles shown in Figure 9 evidenced reductions in hydrocarbon emissions when the aromatics content was increased. Where it is desired to take advantage of this fact, the aromatics content would

5   be increased to at least 35 volume percent, preferably at least 40 volume percent.

In view of the information presented above, a petroleum refiner may take advantage of the invention by

10   blending hydrocarbon streams boiling in the gasoline range of 77° F. (25° C.) to about 437° F. (225° C.) so as to affect at least one (and preferably more than one) of the properties of one of the streams as follows:

        (1) decrease the 50% D-86 Distillation Point;

15   (2) decrease the olefin content;

        (3) increase the paraffin content;

        (4) decrease the Reid Vapor pressure;

        (5) increase the Research Octane Number;

        (6) decrease the 10% D-86 Distillation Point;

20   (7) decrease the 90% D-86 Distillation Point; and

        (8) increase the aromatics content.

In such case, the petroleum refiner is, in essence, using the information provided by the present invention so as to

25   convert a given gasoline stream into another with better properties with respect to CO, NOx, and/or hydrocarbon emissions.

It will also follow that one can increase or

30   decrease any combination of the eight properties listed above, i.e., at least two, at least three, at least four, etc., of the properties can be increased or decreased in the direction indicated above, as well as all eight. In addition, the greater any individual property is changed

35   in the direction indicated, the better the result, with at

least 10% changes being normally used, and preferably at
least 20%. In addition, one can change the property by
difference instead of by percentage, for example, affecting
the properties as follows:

5   (a) decreasing the 50% D-86 distillation point
by at least 20° F. (11.1° C.) or by at least 40° F.
(22.1° C.);

           (b) decreasing the Reid Vapor Pressure by at
least 1 psi (0.07 atm.) or by at least 2 psi (0.14 atm.);

10   (c) decreasing the olefin content by at least 3
volume percent or by at least 5 volume percent;

           (d) increasing the paraffin content by at least
10 volume percent by at least 20 volume percent.

           (e) decreasing the 10% D-86 distillation point
15 by at least 10° F. (5.5° C.) or by at least 20° F.
(11.1° C.); and

           (f) increasing the aromatics content by at least
10 volume percent. Moreover, as would stand to reason,
one could also elect to employ any combination of (a) to
20 (f) above to produce the desired lower emission gasoline
product.

           While the invention may be used to advantage
even on a small volume basis, e.g., a single automobile
25 operating with a fuel composition of the invention for a
week or for at least 200 consecutive miles, it is clear
that the benefits offered by the invention are best taken
advantage of when a large number of automobiles operating
with spark induced internal combustion engines requiring a
30 gasoline fuel are powered with the fuel of the invention.
In fact, the benefits of the invention increase directly
with the number of automobiles which employ the fuel.
Therefore, in one embodiment of the invention, on a given
day, and preferably on a daily basis over a period of at
35 least one month, at least 1,000 and more preferably at

least 10,000 automobiles are provided with a fuel composi-
tion of the invention--and even more preferably it is
desired that the 1000+ or 10,000+ automobiles be provided
with such fuel in a highly congested area, e.g., within

5   the limits of a city or county encompassing a population
of 500,000 or more people. Most advantageously, the
amount of fuel dispensed into automobile fuel tanks within
the city or county should be sufficient to effect a
noticeable decrease in the amount of one or more of NOx,

10   CO, and hydrocarbons in the air. At the present time, it
is believed that, if as little as 10% of the gasoline fuel
supplied to automobiles within a given city or county were
a composition of the invention, a decrease in the pollution
caused by one or more of these components would be obtained

15   (assuming no significant increase in the automobile
traffic within said city or county). Higher percentages,
e.g., at least 25%, will yield still better results. If
at least 50% of the fuel sold within a given city or
county on a daily basis were a composition of the inven-

20   tion, it is believed, based on the data in the Examples
hereinabove, that reductions in auto emissions of CO, NOx,
and/or hydrocarbons at least as high as 20% as compared to
the typical gasoline fuel could be observed (depending, of
course, on how each of the variables is adjusted in the

25   appropriate direction and the magnitude of such changes).
Yet better results can be expected if at least 75%, even
more preferably at least 90%, of the gasoline fuel were
supplied on a given day from gasoline service stations
within a given geographical area, e.g., a governmental

30   district such as a city or county. Alternatively, if the
same percentages pertained to a specific unit area, e.g.,
any 5,000 square mile (12,948 square kilometer) or 10,000
square mile (25,895 square kilometer) or any 50,000 square
mile (129,476 square kilometer) area, one would expect to

35   see reductions in one or more of CO, NOx, and hydrocarbons.

In any event, because the benefits of the invention are best realized when the gasoline fuel of the invention is supplied and combusted on a large quantity basis (i.e., large volume consumption), it is contemplated

5 that there are many ways by which this can be accomplished, among which the following are merely illustrative:

1. Operating a fleet of automotive vehicles, numbering at least 10, preferably at least 25, with a fuel composition of the invention.

10 2. Operating a single automobile for an extended period of time, e.g., at least six months, or for at least 2,000 consecutive miles (3,218 kilometers), with a fuel composition of the invention.

3. Consuming at least 500 gallons (1,893 liters)

15 of a fuel composition of the invention in one vehicle.

4. Consuming at least 2,000 gallons (7,570 liters) of a fuel composition of the invention in either one automobile or a fleet of automobiles.

20 Yet greater consumption can be attained by, for example:

1. Supplying, via gasoline service stations and the like, at least 1,000 vehicles, preferably at least 10,000 vehicles, per day with a fuel composition of the

25 invention.

2. Supplying, via gasoline service stations and the like, at least 10,000,000 gallons (37,850,000 liters) per week of a fuel composition of the invention to automotive vehicles.

30

In order to supply and consume a gasoline composition of the invention on a large volume basis, it follows that the gasoline composition must be produced at a petroleum refinery or the like in large volumes.

35 Typically, a refinery has a capacity to process at least

20,000 barrels per day (132,500 liters per hour), prefer-
ably at least 30,000 barrels per day (198,750 liters per
hour), of crude oil and to produce at least 30,000 gallons
(113,550 liters), preferably at least 50,000 gallons
5   (189,250 liters), and most preferably at least 100,000
gallons (378,500 liters) of gasoline per day. While the
invention would best be taken advantage of if all the
gasoline fuel produced in a refinery were a composition of
the invention, good results can be obtained if a signif-
10   icant fraction thereof--e.g., at least 10%, were a fuel
composition of the invention. In commercial practice, it
is contemplated that usual procedures will result in at
least 25%, often at least 50%, and sometimes at least 75%
of the daily refinery output being a fuel composition of
15   the invention. Such output would then be delivered to
gasoline service stations for introduction into automobiles,
with, again, the greatest significant advantage being if
all the gasoline service stations so supplied--or some
significant portion thereof, e.g., at least 25%, more
20   preferably at least 50%, and most preferably at least
75%--are located in a congested area of high population
density, e.g., a city or county as described above.

Accordingly, in view of the foregoing, it will
25   be seen that there are many ways of employing the inven-
tive concept on a large volume basis. Obviously, the best
results will be obtained when the fuel composition of the
invention is so blended in a refinery or the like as to
reduce the emissions of hydrocarbons, CO, and NOx to the
30   lowest possible levels, then combusting such fuel in
automobiles on a large volume basis over extended periods
of time, e.g., at least one month, preferably at least six
months, and with the most advantage to be realized in the
most densely populated areas, e.g., counties or cities of
35   populations exceeding 1,000,000, or more than 2,500,000,

or more than 5,000,000, or, in areas like Los Angeles
county, more than 10,000,000 persons. To provide for the
needs of such high population density areas, it may be
necessary to supply the fuel composition of the invention

5   from more than one refinery, and to deliver it to a large
fraction of the gasoline service stations in such area,
e.g., at least 25%, preferably at least 50%, most prefer-
ably at least 75%, so that a large number of automobiles
can be supplied with the inventive fuel on a daily basis,

10   e.g., at least 100,000, preferably at least 500,000
automobiles.

           In view of the foregoing, it can be seen that
the invention offers many advantages, not the least of

15   which are the obvious health benefits associated with
reduced air pollutants emitted to the atmosphere from
automobiles, trucks, and other gasoline powered motor
vehicles. Additionally, the invention can be put into
immediate practice; current refining equipment can be

20   employed to produce the low polluting fuels of the inven-
tion. Moreover, the invention offers the petroleum
refiner a great deal of flexibility, for the invention is
highly adaptable to a wide variety of hydrocarbon refinery
streams. More specifically, since the description herein-

25   before shows the effect of different variables, the
refiner is not constrained to producing one particular
fuel, but has several options, depending on what hydro-
carbon streams are at hand and what properties of the fuel
can be most easily altered.

30

           By offering such flexibility with no needed
hardware changes in a refinery, the invention is relatively
easy to implement--and all the more so in light of the
fact that the invention can be taken advantage of without

35   need for additives specific for reducing polluting emissions.

As an example, many current fuels contain methyl tertiary butyl ether as an additive for reducing CO emissions. The present invention, however, requires no methyl tertiary butyl ether to be present. Thus, while the invention in

5   its broadest embodiment encompasses fuels with additives that may aid in reducing such emissions, the advantages of the invention can be obtained without the necessity, for example, of a refinery having to deliberately change its practices to provide for the continuous blending of an

10   emission-reducing additive into the fuel.

The invention, of course, as described herein-before, offers significant reductions in NOx, CO, and hydrocarbon emissions. Present indications are that, on a

15   side-by-side basis, preferred fuels of the present invention offer at least a 10%, usually at least a 20%, sometimes at least 40%, reduction in emissions when tested in identical vehicles (e.g., the 1988 Oldsmobile Regency 98 described above) with identical engines and identical

20   catalytic converter systems as compared to results obtained with a typical fuel, for example, the fuel identified in Table 2 as A/O AVE and that in Table 5 as Fuel Q. (These fuels are, in essence, identical, having been made in identical fashion but at different times; the slight

25   differences in results shown in the two tables being within normal tolerance variations.)

It should also be recognized that the invention offers an advantage for automobile manufacturers. As

30   government regulations progressively become more stringent in the amount of pollutants that can be emitted from motor vehicles, the present invention, by providing for a fuel inherently having properties which reduce or minimize such emissions, allows an automobile manufacturer to meet such

35   regulations with fewer--if any--hardware design changes being needed.

It will be understood that reference hereinabove to the "D-86 Distillation Point" refers to the distillation point obtained by the procedure identified as ASTM D 86-82, which can be found in the 1990 Annual Book of ASTM Stand-

5   ards, Section 5, Petroleum Products, Lubricants, and Fossil Fuels, herein incorporated by reference in its entirety.

The FTP (Federal Test Procedure) specified

10   hereinabove refers to Code of Federal Regulations, volume 40, "Protection of the Environment," Subpart B, "Emission Regulations for 1977 and Later Model Year New Light-Duty Vehicles and New Light-Duty Trucks; Test Procedures, herein incorporated by reference in its entirety.

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"Reid Vapor Pressure" is a pressure determined by a conventional analytical method for determining the vapor pressure of petroleum products. In essence, a liquid petroleum sample is introduced into a chamber, then

20   immersed in a bath at 100° F. (37.8° C.) until a constant pressure is observed. Thus, the Reid Vapor Pressure is the difference, or the partial pressure, produced by the sample at 100° F. (37.8° C.). The complete test procedure is reported as ASTM test method D 323-89 in the 1990

25   Annual Book of ASTM Standards, Section 5, Petroleum Products, Lubricants, and Fossil Fuels, herein incorporated by reference in its entirety.

While the invention has been described in

30   conjunction with preferred embodiments thereof, various modifications and substitutions can be made thereto without departing from the spirit and scope of the present invention. The invention has also been described with reference to examples, which are presented for illustra-

35   tion only, and thus no limitation should be imposed other than those indicated by the following claims: